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RESEARCH MEMORANDUM

INVESTIGATION AT TRANSONIC SPEEDS OF THE EFFECT OF A POSITIVE-LIFT BALANCING TAB ON THE HINGE-MOMENT AND LIFT CHARACTERISTICS OF A FULL-SPAN FLAP ON A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3

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INVESTIGATION AT TRANSONIC SPEEDS OF THE EFFECT OF A POSITIVE-LIFT BALANCING TAB ON THE HINGE-MOMENT AND LIFT CHARACTERISTICS OF A FULL-SPAN FLAP ON A TAPERED 45° SWEPTBACK WING OF ASPECT RATIO 3

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SUMMARY

An investigation has been made at transonic speeds to determine the control characteristics of a linked tab and flap. The control consisted of an auxiliary lifting surface (tab) mounted on the end of a boom which was linked to a full-span flap such that a positive lift on the flap and the tab produced opposing hinge moments and additive lift. The control was mounted on a 7.6-percent-thick, tapered, 45° swept wing of aspect ratio 3. The investigation was made in the Langley high-speed 7- by 10-foot tunnel.

The results indicated that the tab was capable of reducing the flap hinge moments to zero (flap deflection 3.9°) through the range of these tests but there was considerable variation in the required tab-flap deflection ratio (approximately 2 to 4) with Mach number. The balanced control gave equal or greater lift effectiveness than the unbalanced control through the range of the tests.

INTRODUCTION

At the present time the NACA is investigating various types of aerodynamically balanced control surfaces in the transonic speed range. Balancing devices such as overhangs, horns, tabs, auxiliary lifting surfaces, and combinations thereof are being considered. Some preliminary investigations have been made on some of these controls, the results of which are presented in references 1 to 5. In all of these investigations, as in the present case, no attempt is being made to obtain design information. The emphasis is being placed, however, on finding whether the balancing device or combinations thereof appear promising at transonic speeds.

One method of balance which has been successful at low speeds and, from the data of reference 3, appears promising at high speed is the balancing tab. An undesirable feature of the conventional balancing tab is the loss of lift of the control resulting from an oppositely deflected tab. The present investigation is concerned with a proposed balancing tab which would overcome the loss in lift usually associated with conventional tabs; that is, the lift of the tab would be additive to the lift of the main control. The device is somewhat similar to one suggested by a representative of the Douglas Aircraft Company.

The control arrangement of the present investigation consisted of an adjustable auxiliary lifting surface mounted on the end of a boom which was linked to a full-span flap such that a positive lift on the flap and the tab produced opposing hinge moments and additive lift. (In practice the adjustable surface could be a servocontrol.) The investigation was made on a tapered, 45° swept wing of aspect ratio 3. The lift and hinge-moment characteristics are presented. The hinge moments measured were those of the flap-tab combination. The results are presented for an angle-of-attack range from 0° to 16° at a flap deflection of 3.9° from a Mach number of 0.70 to 1.10. The Reynolds number of the investigation was approximately 1,000,000.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient, Twice semispan lift/qS

C_{h_f} flap hinge-moment coefficient,
Flap hinge moment about hinge line of semispan flap/q2M'

S twice wing area of semispan model, 0.202 sq ft

b twice semispan of model, 0.778 ft

$\bar{c}$ mean aerodynamic chord of wing, 0.269 ft, $\frac{2}{S}\int_0^{b/2} c^2 dy$

M' area moment of semispan flap rearward of the hinge line about the hinge line, 0.000692 ft^3

q effective dynamic pressure over span of model, $\frac{1}{2}\rho V^2$, lb/sq ft

c	local wing chord, ft
y	spanwise distance from plane of symmetry, ft
ρ	mass density of air, slugs/cu ft
V	free-stream velocity, ft/sec
M	effective Mach number over span of model, $\frac{2}{S}\int_0^{b/2} cM_a dy$
M_a	average chordwise local Mach number
M_l	local Mach number
R	Reynolds number of wing based on $\bar{c}$
α	angle of attack, deg
δ_f	flap deflection relative to wing-chord plane, measured in a plane parallel to plane of symmetry (positive when trailing edge is down), deg
δ_t	tab deflection relative to boom measured in a plane parallel to plane of symmetry (positive when trailing edge is down), deg
δ_b	boom deflection relative to wing-chord plane, measured in a plane parallel to plane of symmetry (positive when down), deg

Parameters:

$$C_{h_{f\delta_t}} = \left(\frac{\partial C_{h_f}}{\partial \delta_t}\right)_{\alpha,\delta_f=3.9^\circ}$$

$$\left(C_{h_{f\delta_f}}\right)_{\delta_t=0} = \left(\frac{\partial C_{h_f}}{\partial \delta_f}\right)_{\alpha,\delta_t=0}$$

$$C_{L_{\delta_t}} = \left(\frac{\partial C_L}{\partial \delta_t}\right)_{\alpha,\delta_f=3.9^\circ}$$

$$\left(C_{L_{\delta_f}}\right)_{C_{h_{\delta_f}}=0} = \left(\frac{\partial C_L}{\partial \delta_f}\right)_{\alpha, C_{h_{\delta_f}}=0}$$

$$C_{h_{\delta_f}} = C_{h_{f_{\delta_f}}} - C_{h_{f_{\delta_t}}} \frac{\delta_t}{\delta_f}$$

The subscripts outside the parentheses indicate the factors held constant during the measurement of the parameters. The parameters $C_{h_{f_{\delta_t}}}$ and $C_{L_{\delta_t}}$ were measured between approximately 0° and 16° tab deflection.

MODEL AND APPARATUS

The steel semispan model used in the investigation had a quarter-chord sweep angle of 45.58°, an aspect ratio of 3, a taper ratio of 0.5, and was approximately 7.6 percent thick. The airfoil section was an NACA 64A010 measured in a plane at 45° to the plane of symmetry. The pertinent dimensions of the basic wing are given in figure 1 and a photograph of a typical wing mounted on the reflection plane is shown in figure 2. The wing was equipped with a full-span plain flap-type control of 25.4 percent of the chord measured parallel to the plane of symmetry. The wing was also equipped with an aerodynamic balancing mechanism which consisted of a triangular auxiliary lifting surface (tab) mounted at the end of a boom which rotated about a hinge line ahead of the flap as shown in figure 3. The boom was linked to the flap so that as the flap was deflected down the boom was deflected up (3.9° flap deflection = −4.1° boom deflection). The tab hinge line was located slightly ahead of the apex of the tab. In this case the tab was rigidly attached to the boom and was deflected positively. (In order to act as a balance the tab must be hinged to the boom and activated in a sense opposite in direction and at a greater rate of deflection than that for the boom.) The tab area was approximately 6.9 percent of the flap area. The hinge moments of the flap-tab combination were indicated by a strain-gage beam attached to the flap shaft. The model was mounted on an electrical strain-gage balance which was attached to the tunnel wall and shielded from the air stream. The model butt extended through a turntable in the reflection-plane plate with a clearance gap of about 1/16 inch. A sponge-rubber seal was attached to the turntable to minimize leakage of air around the butt of the model. Tab deflections were corrected for angle changes due to deflection of the linkage under load.

TESTS

The tests were conducted through an angle-of-attack range from 0° to 16° at a flap deflection of 3.9° with tab deflections from 0° to approximately 16° and over a Mach number range from 0.70 to 1.10. For Mach numbers below 0.95 there was practically no gradient in the vicinity of the reflection plane. At higher Mach numbers, the presence of the reflection plane created a local high-velocity field which allowed testing the model up to $M = 1.10$ before choking occurred in the tunnel. Typical variations of local Mach numbers are shown in figure 4. The effective test Mach numbers were obtained from contour charts similar to those shown in figure 4, by the relationship

$$M = \frac{2}{S}\int_0^{b/2} cM_a dy$$

For the investigation a chordwise Mach number gradient of generally less than 0.02 was obtained between Mach numbers of 0.95 and 1.04, increasing to about 0.06 at the highest test Mach number of 1.10.

A typical variation of Reynolds number with Mach number is shown in figure 5.

RESULTS AND DISCUSSION

Variation of the flap hinge-moment and lift coefficients resulting from deflection of the tab are presented in figures 6 and 7 for a constant flap deflection of 3.9°. The control parameters are presented in figures 8 to 12. The parameters $C_{h_{f_{\delta_t}}}$ and $C_{L_{\delta_t}}$ presented in figures 8 and 11, respectively, are the average slopes of the coefficient curves against tab deflection between 0° and approximately 16° deflection. The flap parameter $C_{h_{f_{\delta_t}}}$ (fig. 8), which is a measure of the balancing effect of the tab, indicates that its effectiveness is approximately the same through the Mach number range. This might be expected since the tab is a 70° delta surface and lift-curve slopes and centers of pressure from delta wings show little variation with Mach number. The balancing effectiveness shows some reduction at large angles of attack ($\alpha = 12^{\circ}$ and 16°).

The parameter $\left(C_{h_{f_{\delta_f}}}\right)_{\delta_t=0^{\circ}}$ of figure 9 was calculated using the following equation

$$\left(C_{h_{f_{\delta_f}}}\right)_{\delta_t=0^{\circ}} = \left(C_{h_{f_{\delta_f}}}\right)_{\text{plain flap}} + 1.05C_{h_{f_{\delta_t}}}$$

where the values of $\left(C_{h_{f_{\delta_f}}}\right)_{\text{plain flap}}$ are from reference 3. (Values of $C_{h_{f_{\delta_f}}}$ and $C_{L_{\delta_f}}$ from reference 3 were thought to be more accurate than those obtained in this investigation.) The factor 1.05 is the mechanical advantage δ_b/δ_f between boom and flap. The effect of drag on the boom which would tend to be unbalancing has been neglected. It is thought that this effect would be relatively small as the boom is nearly parallel to the wing chord. At higher deflections it would of course have to be considered.

The ratio of $C_{h_{f_{\delta_f}}}$ to $C_{h_{f_{\delta_t}}}$ (that is, δ_t/δ_f) is an indication of the tab deflection required to balance out the flap hinge moments for each degree of flap deflection based on a flap deflection of 3.9°. Considerable variation in the required ratios are noted (approximately 2 to 4). (See fig. 10.) Increases in δ_t/δ_f are generally noted above $M = 0.90$ which are the results of the increases in flap hinge-moment coefficient associated with transonic speeds.

The lift effectiveness of the balanced flap $\left(C_{L_{\delta_f}}\right)_{Ch_{\delta_f} = 0}$ (fig. 12) has been calculated by the equation:

$$\left(C_{L_{\delta_f}}\right)_{C_{h_{\delta_f}}=0} = C_{L_{\delta_f}}\text{ (plain flap, ref. 3)} + C_{L_{\delta_t}}\left(\frac{\delta_t}{\delta_f} - 1.05\right)$$

The lift obtained for this control configuration is in all cases equal to or greater than that obtainable on a plain flap as shown in figure 12.

It should be noted that the results presented herein should be examined from a qualitative viewpoint because the tab design does not represent a practical arrangement in that this tab arrangement was so located that it was possible to deflect the boom in only one direction. A more practical arrangement of this balancing device would be to place the booms at the end of each flap and link the tab, boom, and flap through a gear train or other suitable linkage to obtain the required balancing action. Another arrangement would be a servotab with the tab linked to the stick so that the pilot would control the tab deflection which in turn would control the flap deflection.

CONCLUDING REMARKS

An investigation at transonic speeds of a 7.6-percent-thick, 45° sweptback wing of aspect ratio 3 having a full-span flap set at a deflection of 3.9° and linked to an auxiliary lifting surface indicated the following:

1. The tab was capable of reducing the flap hinge moment to zero throughout the angle-of-attack and Mach number range tested.

2. The variation in tab-flap deflection ratios required for zero flap hinge moment with Mach number was generally small up to $M = 0.90$ but was considerably more at higher Mach numbers.

3. The balanced control gave lift effectiveness equal to or greater than that of the unbalanced control throughout the angle-of-attack and Mach number range tested.

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REFERENCES

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2. Lowry, John G., and Fikes, Joseph E.: Preliminary Investigation of Control Characteristics at Transonic Speeds of a Tapered 45° Sweptback Wing of Aspect Ratio 3 Having a Horn-Balanced Full-Span Control. NACA RM L52A11, 1952.

3. Lockwood, Vernard E., and Fikes, Joseph E.: Preliminary Investigation at Transonic Speeds of the Effect of Balancing Tabs on the Hinge-Moment and Other Aerodynamic Characteristics of a Full-Span Flap on a Tapered 45° Sweptback Wing of Aspect Ratio 3. NACA RM L52A23, 1952.

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5. Lockwood, Vernard E., and Fikes, Joseph E.: Control Characteristics at Transonic Speeds of a Linked Flap and Spoiler on a Tapered 45° Sweptback Wing of Aspect Ratio 3. NACA RM L52D25, 1952.

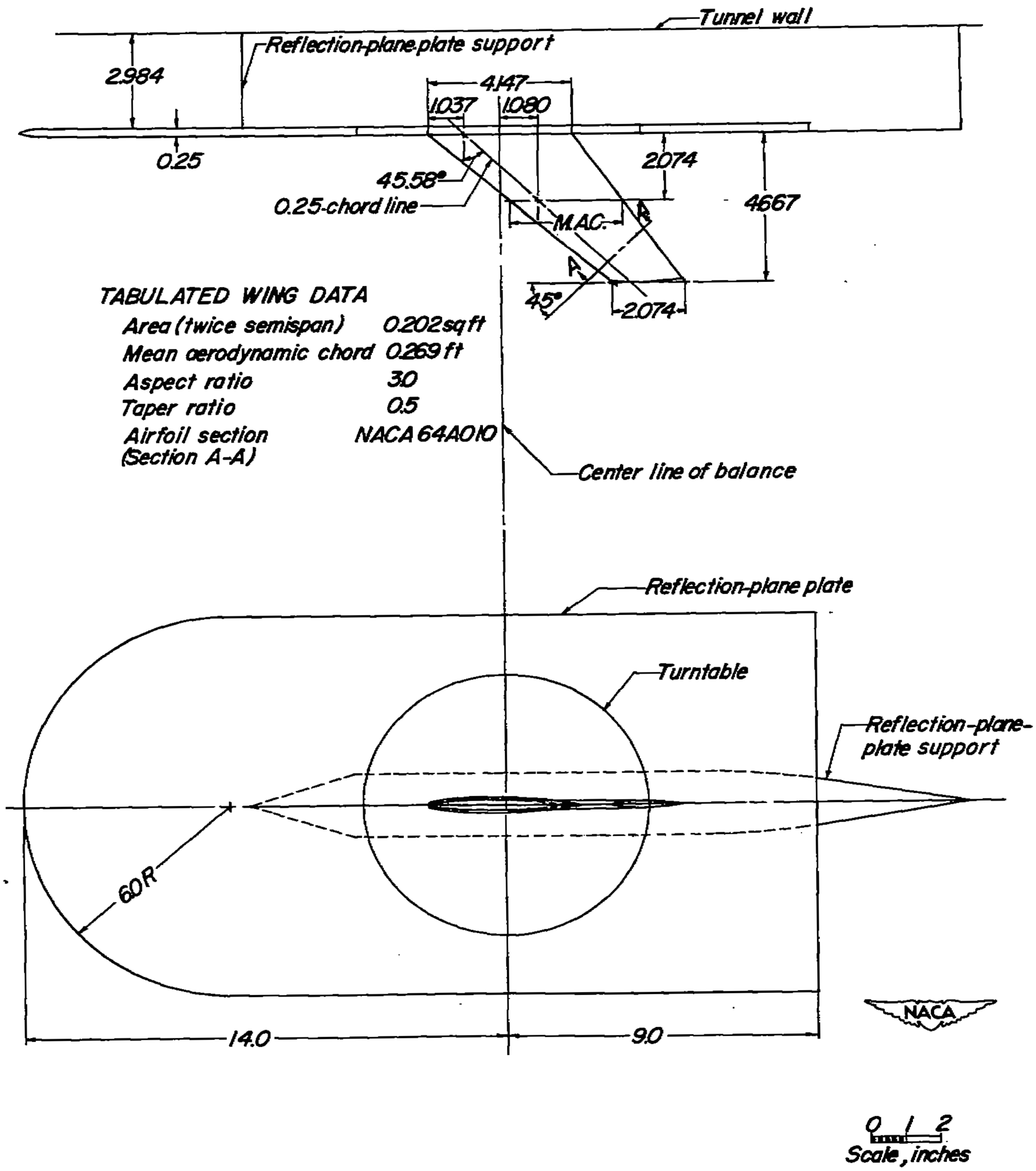


Figure 1.- Basic wing model mounted on the reflection plane in the Langley 7- by 10-foot high-speed tunnel.

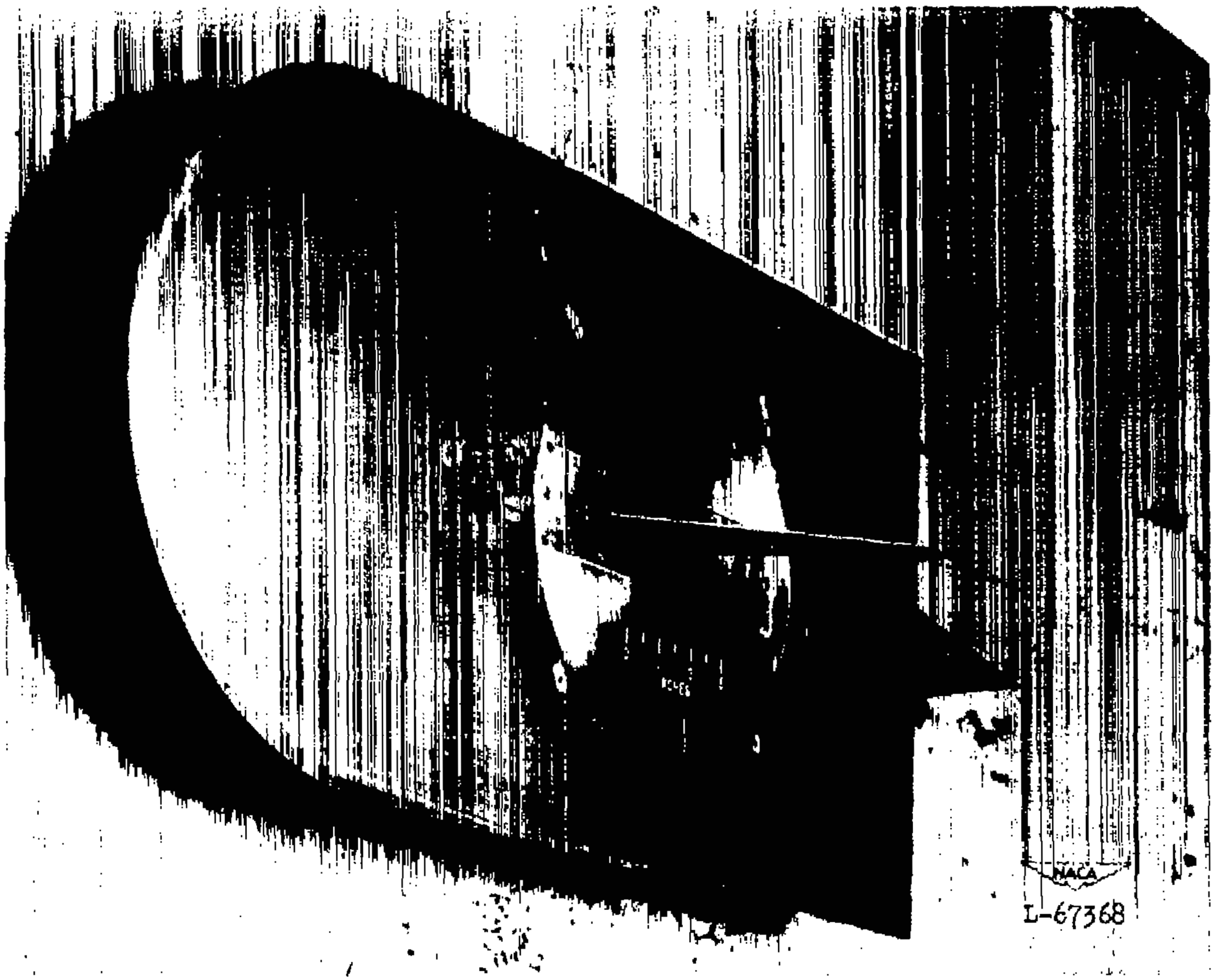


Figure 2.- View of typical model mounted on the reflection plane in the 7- by 10-foot high-speed tunnel.

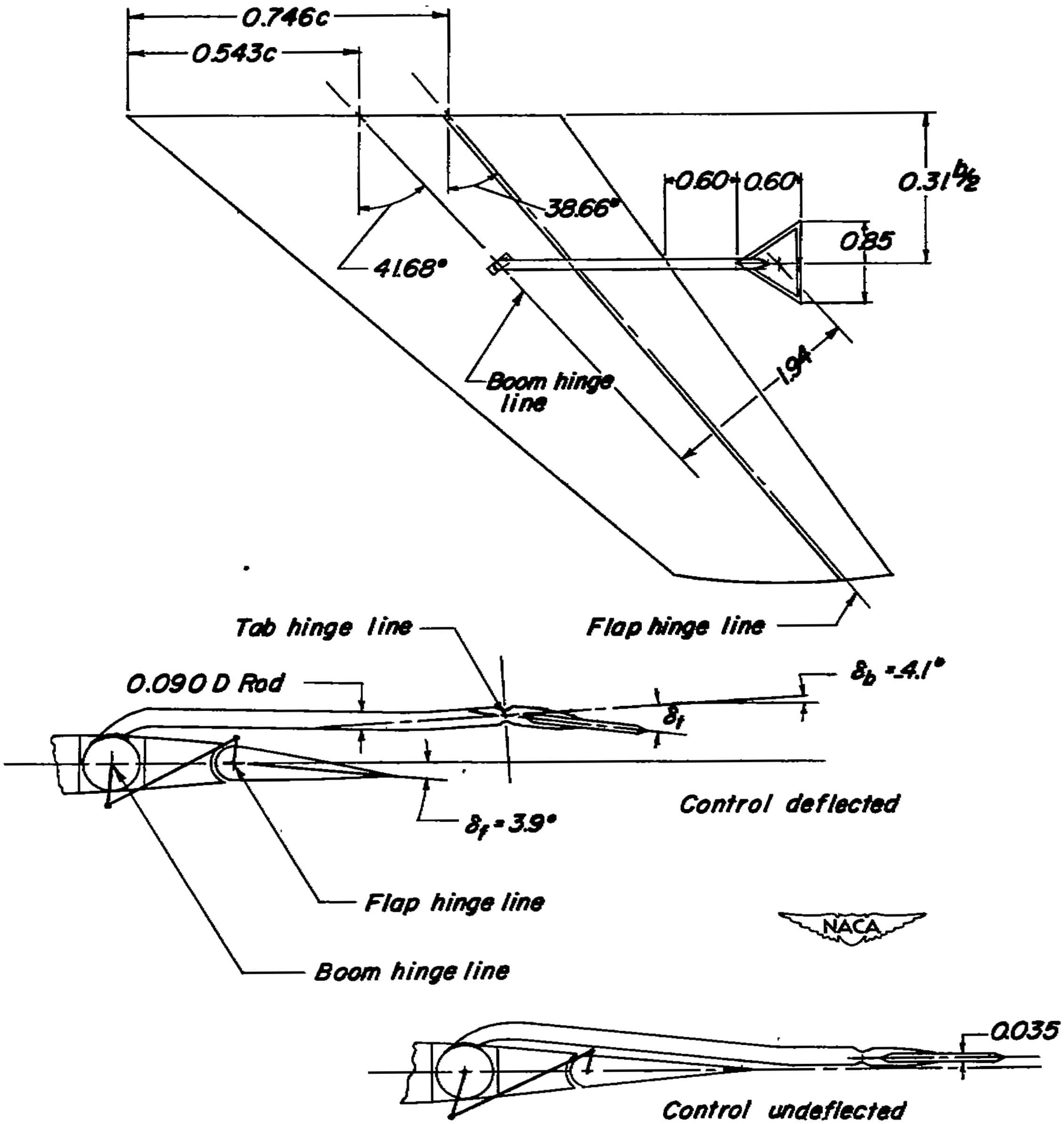


Figure 3.- Details of control tested. All dimensions are in inches.

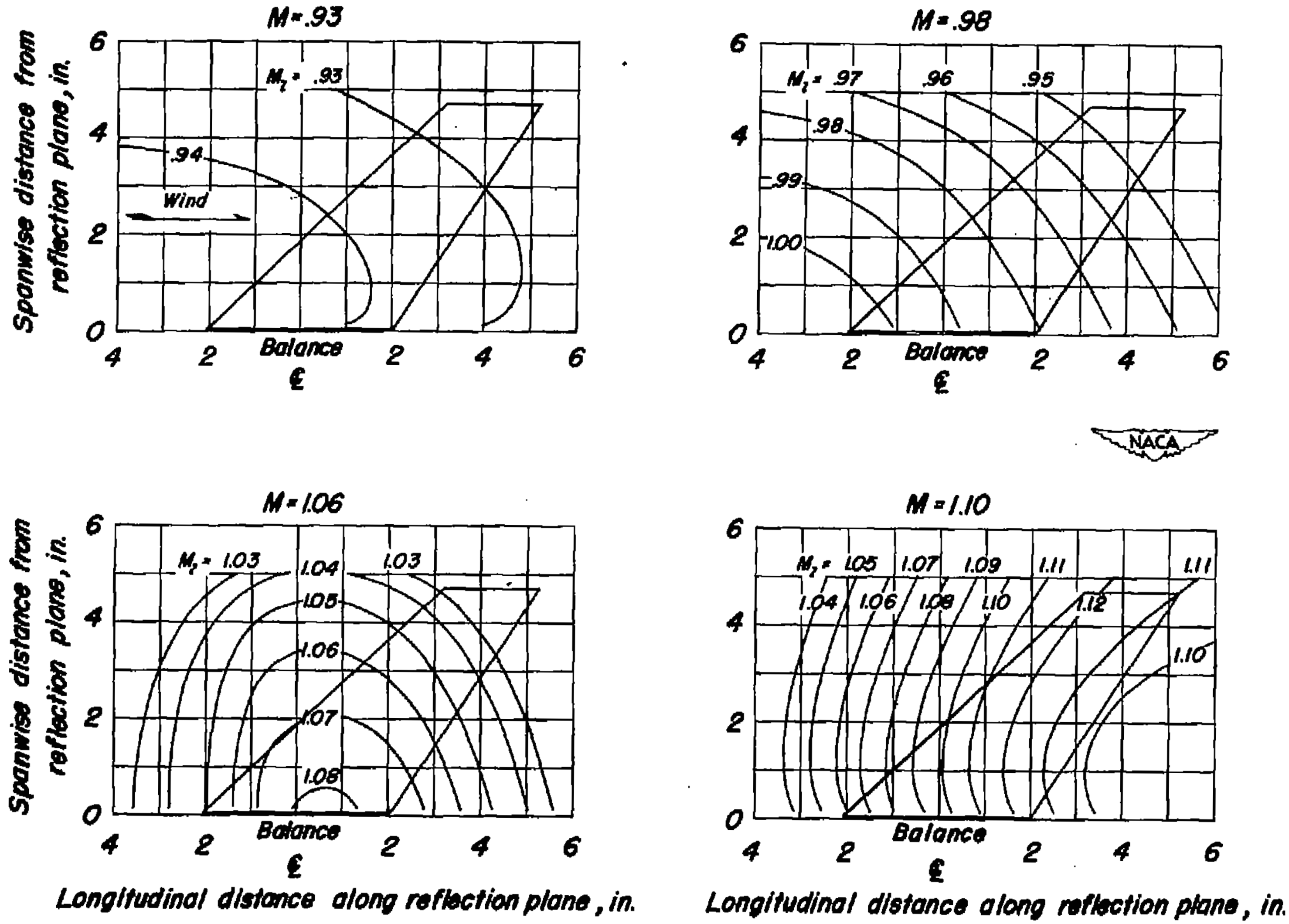


Figure 4.- Typical Mach number contours over the side-wall reflection plane in region of model location.

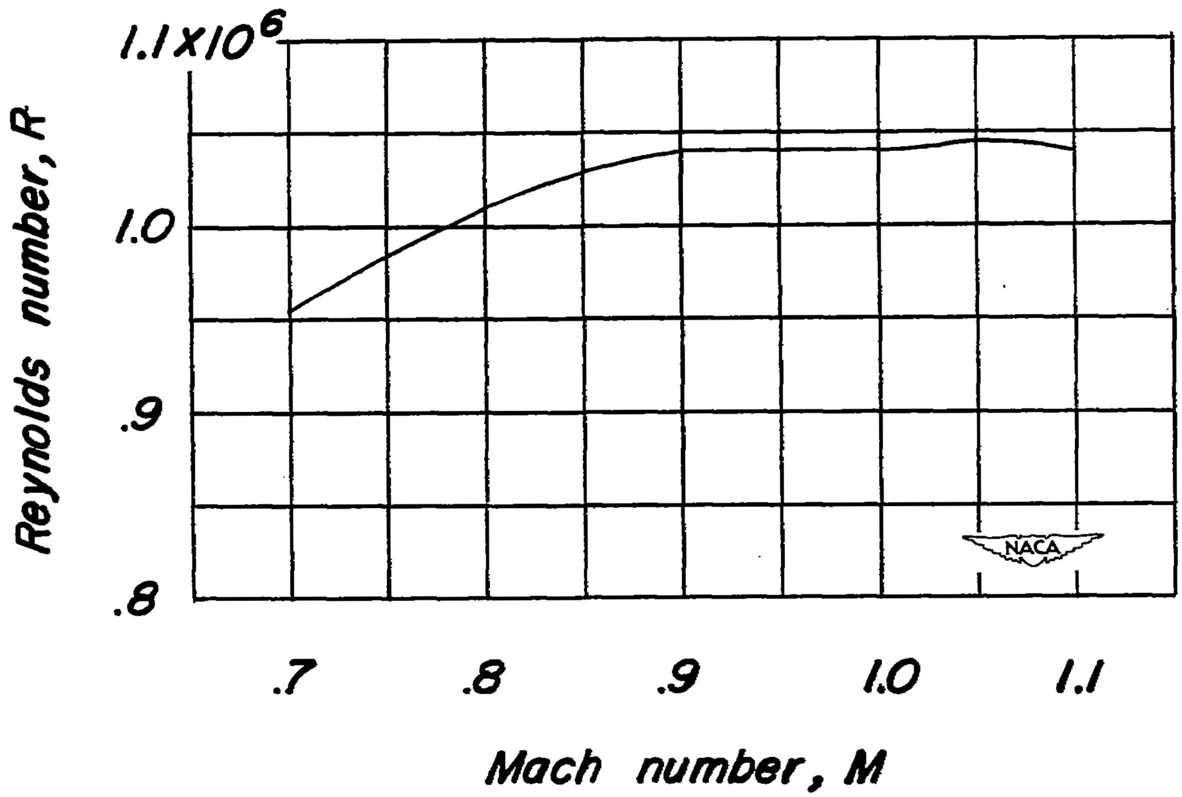
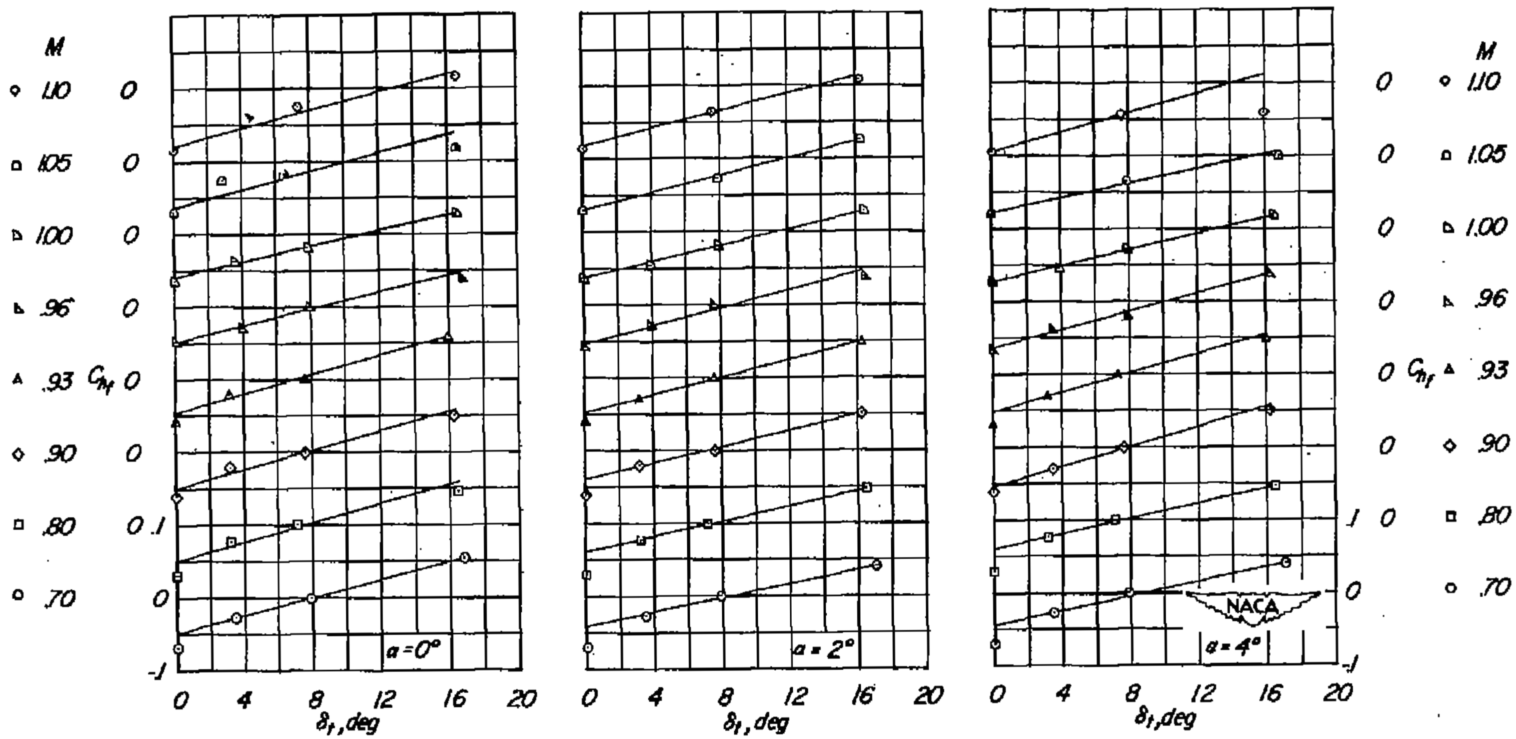
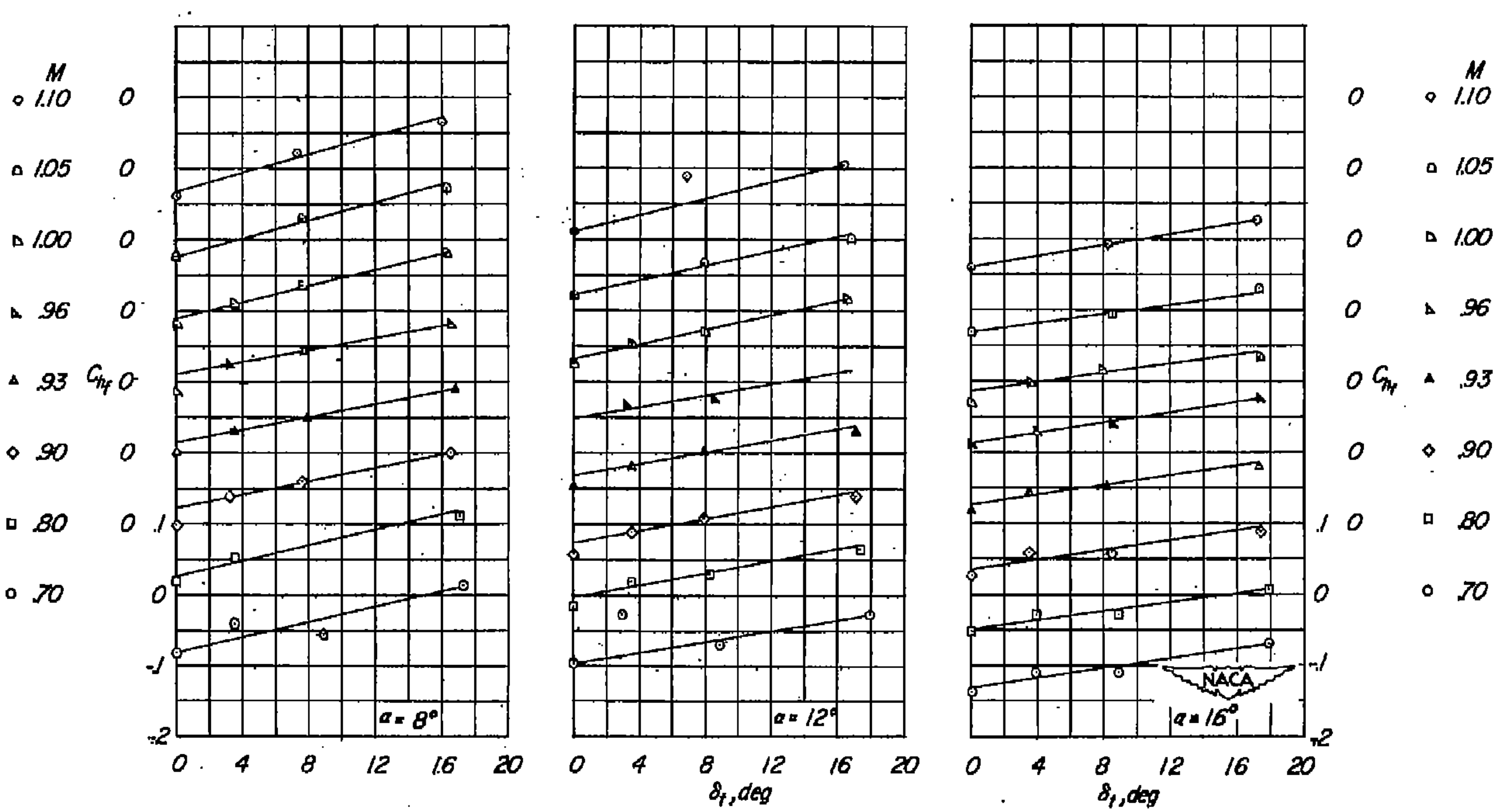


Figure 5.- Typical variation of Reynolds number with test Mach number through the transonic speed range.



(a) $\alpha = 0^{\circ}$ to 4°.

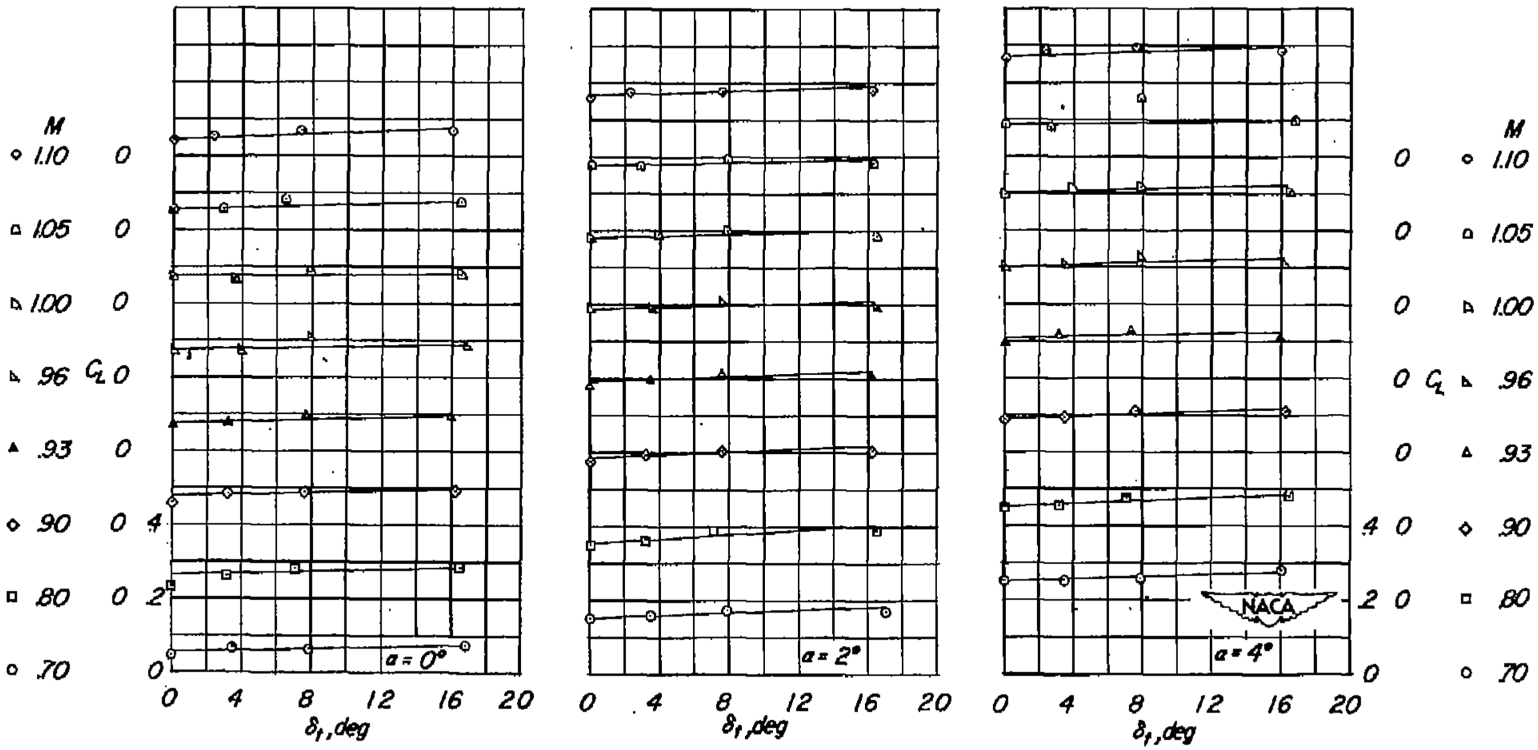
Figure 6.- Variation of flap hinge-moment coefficient with tab deflection for various Mach numbers and angles of attack. $\delta_f = 3.9^{\circ}$.



(b) $\alpha = 8^\circ$ to 16°.

Figure 6.- Concluded.

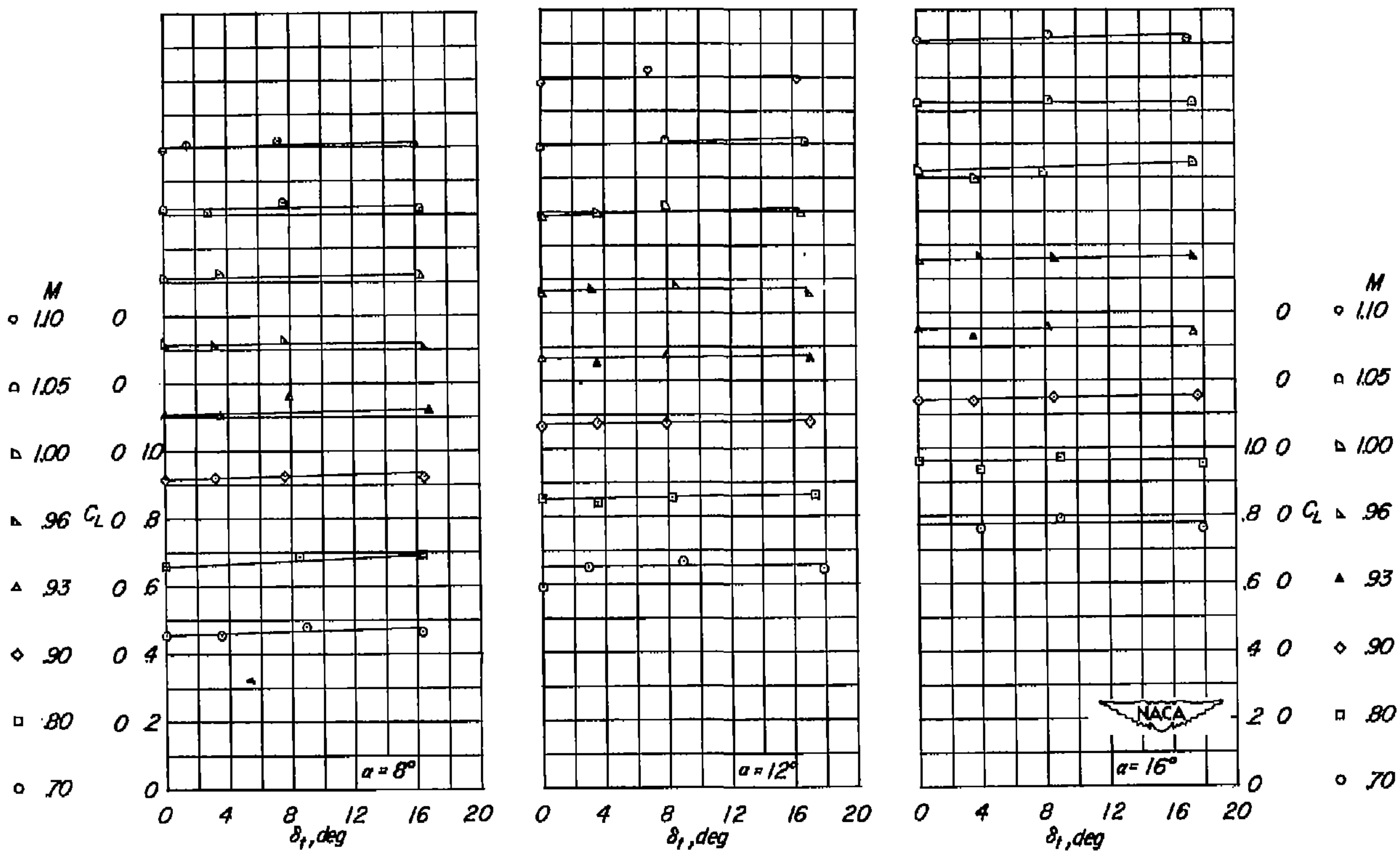
[redacted]



(a) $\alpha = 0^{\circ}$ to 4°.

Figure 7.- Variation of the lift coefficient with tab deflection for various Mach numbers and angles of attack. $\delta_f = 3.9^{\circ}$.

[redacted]



(b) $\alpha = 8^\circ$ to 16°.

Figure 7.- Concluded.

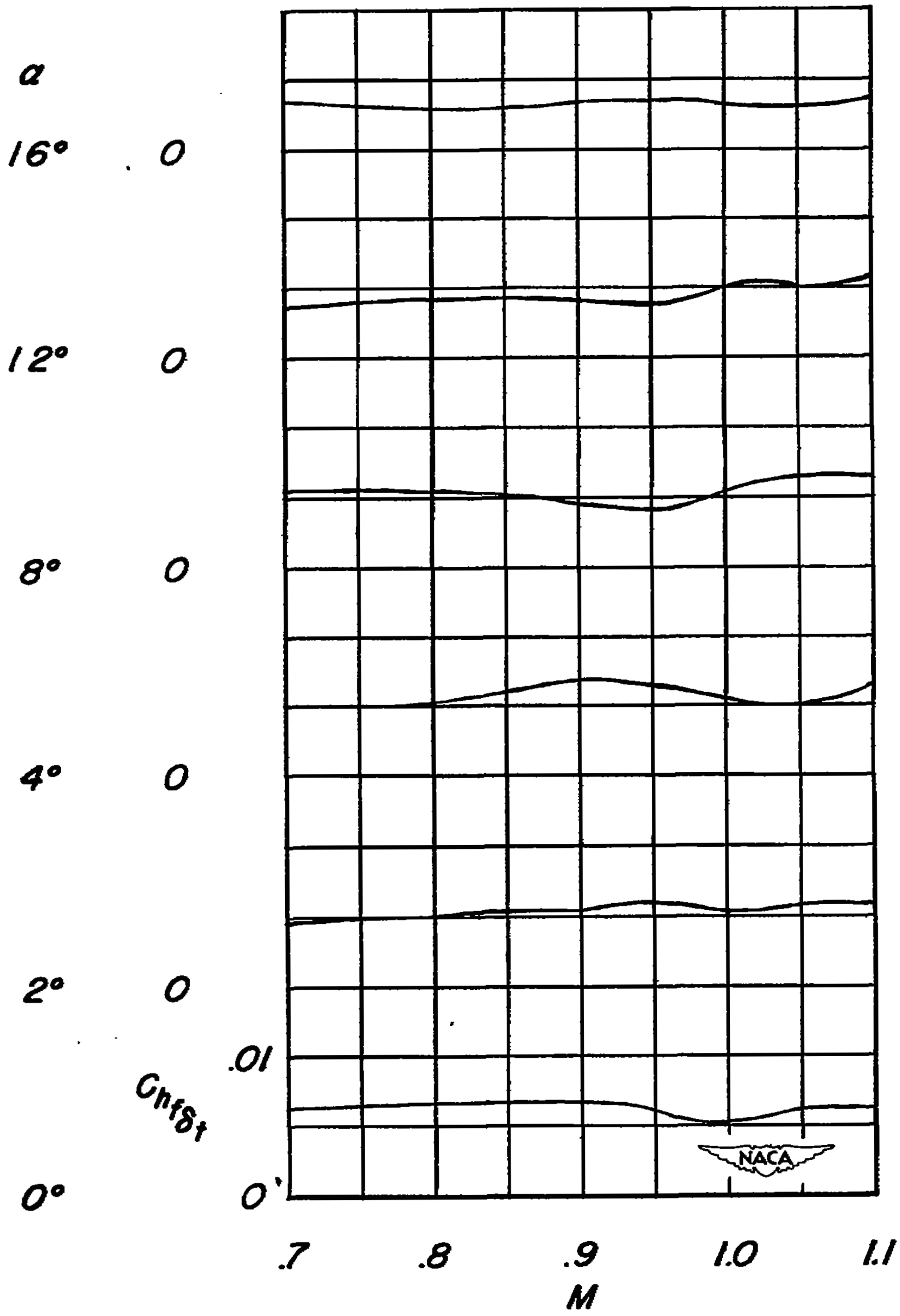


Figure 8.- Variation of the flap hinge-moment parameter $C_{h_{f_{\delta_t}}}$ with Mach number for various angles of attack. $\delta_f = 3.9^{\circ}$.

[redacted]

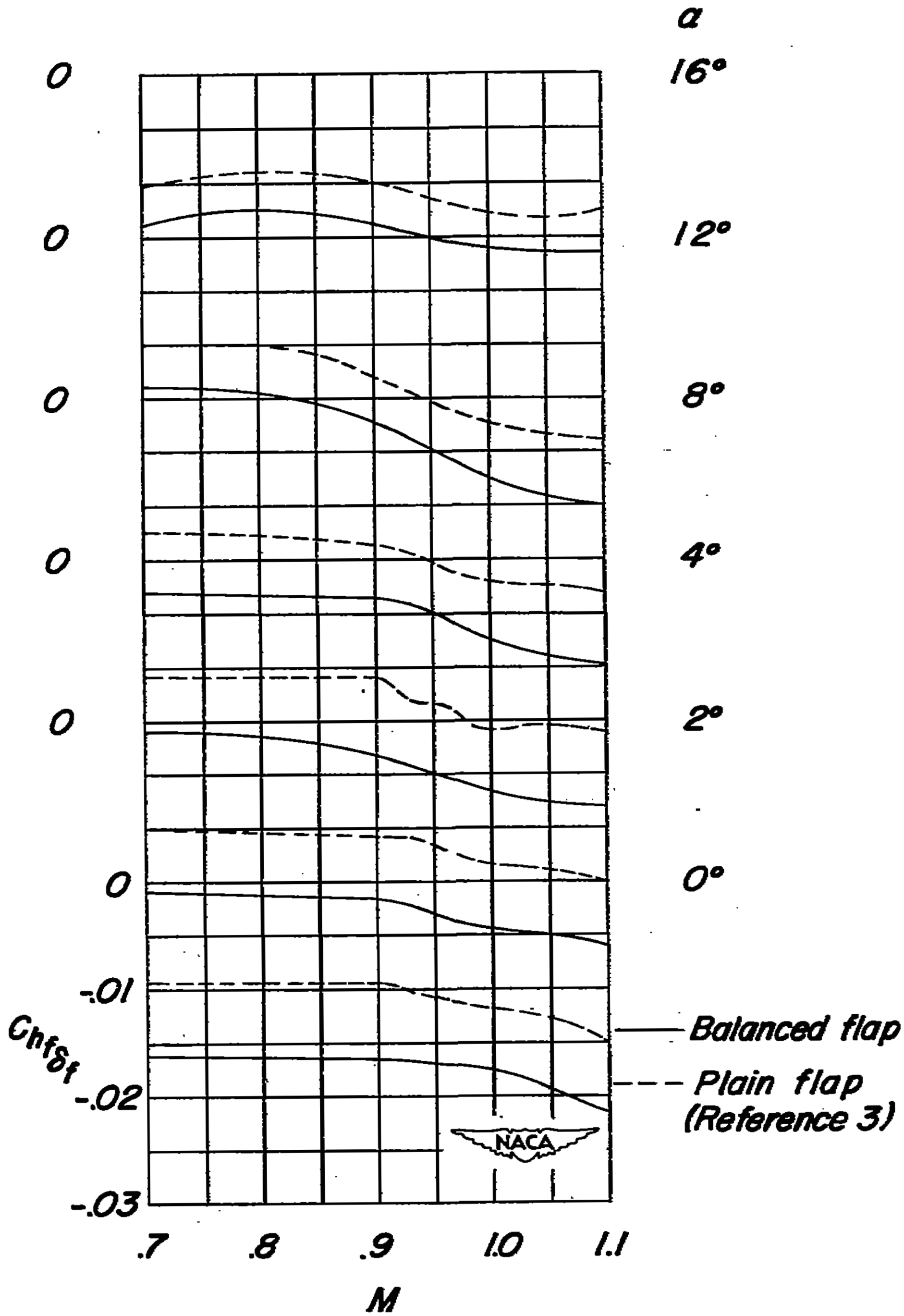


Figure 9.- Variation of the flap hinge-moment parameter $C_{h_{f_{\delta_f}}}$ with Mach number for various angles of attack. $\delta_t = 0^{\circ}$. $C_{h_{f_{\delta_f}}}$ based on the deflection of the flap in the free-stream direction.

[redacted]

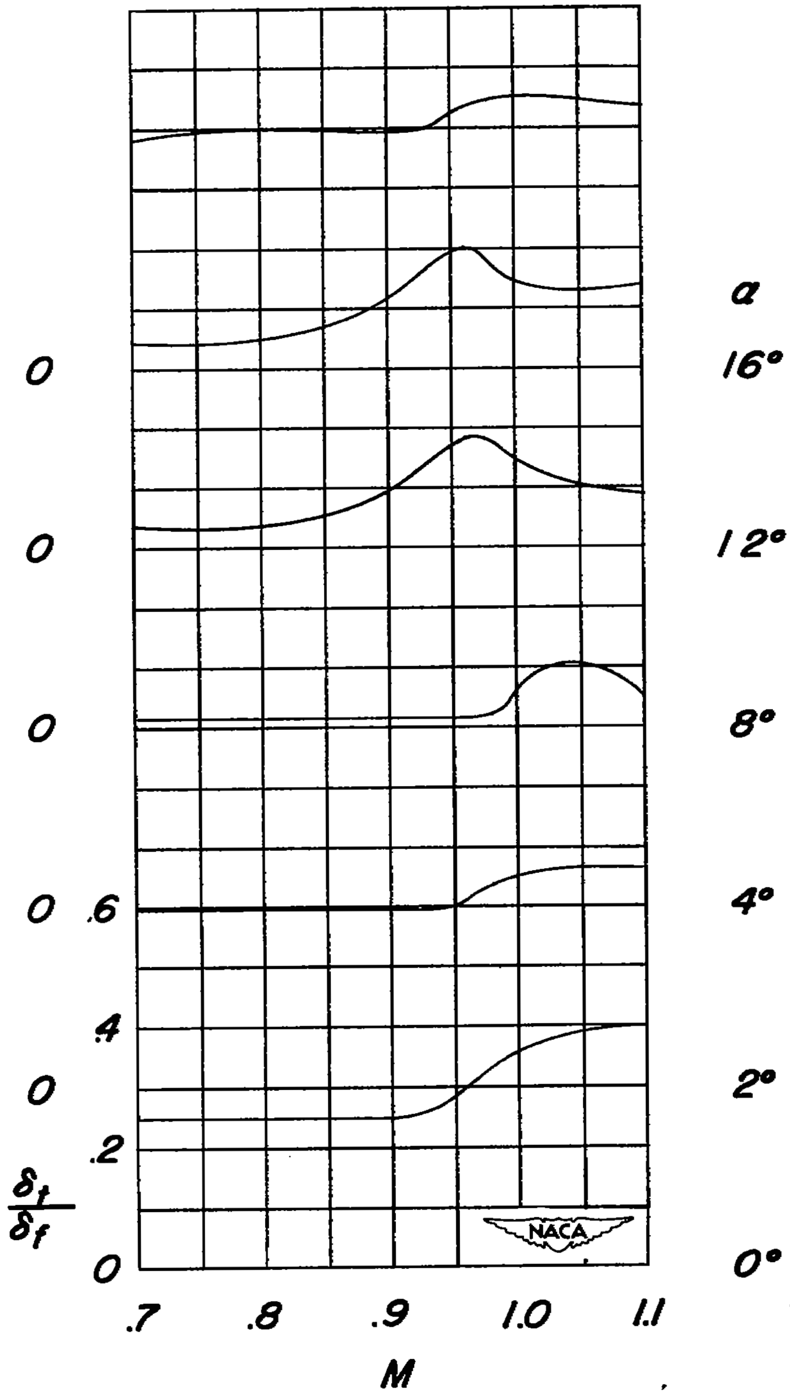


Figure 10.- Ratio of tab deflection to flap deflection required for $C_{h_{\delta_f}} = 0$ for various Mach numbers and angles of attack.

[redacted]

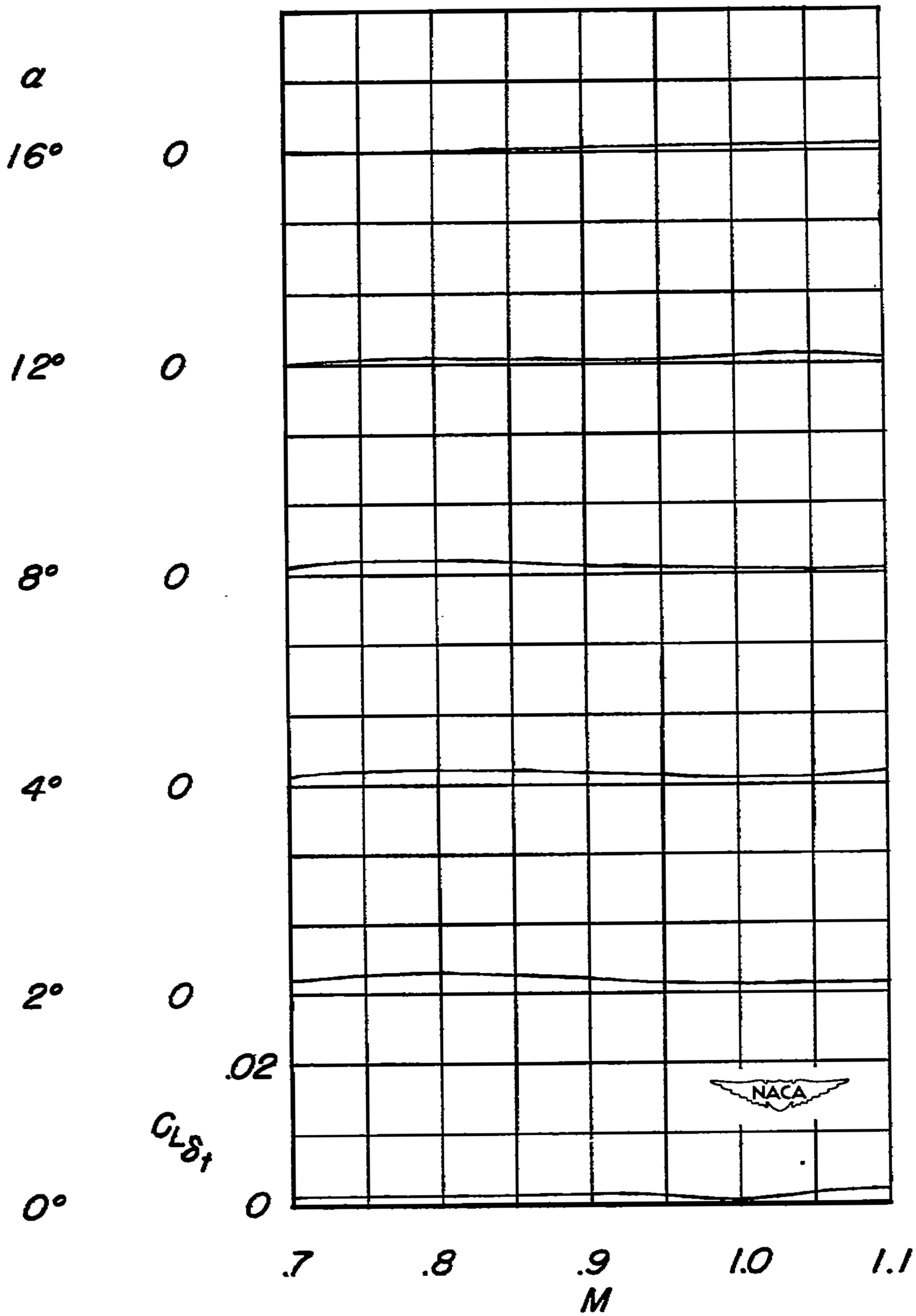


Figure 11.- Variation of the tab lift parameter with Mach number for various angles of attack. $\delta_f = 3.9^{\circ}$.

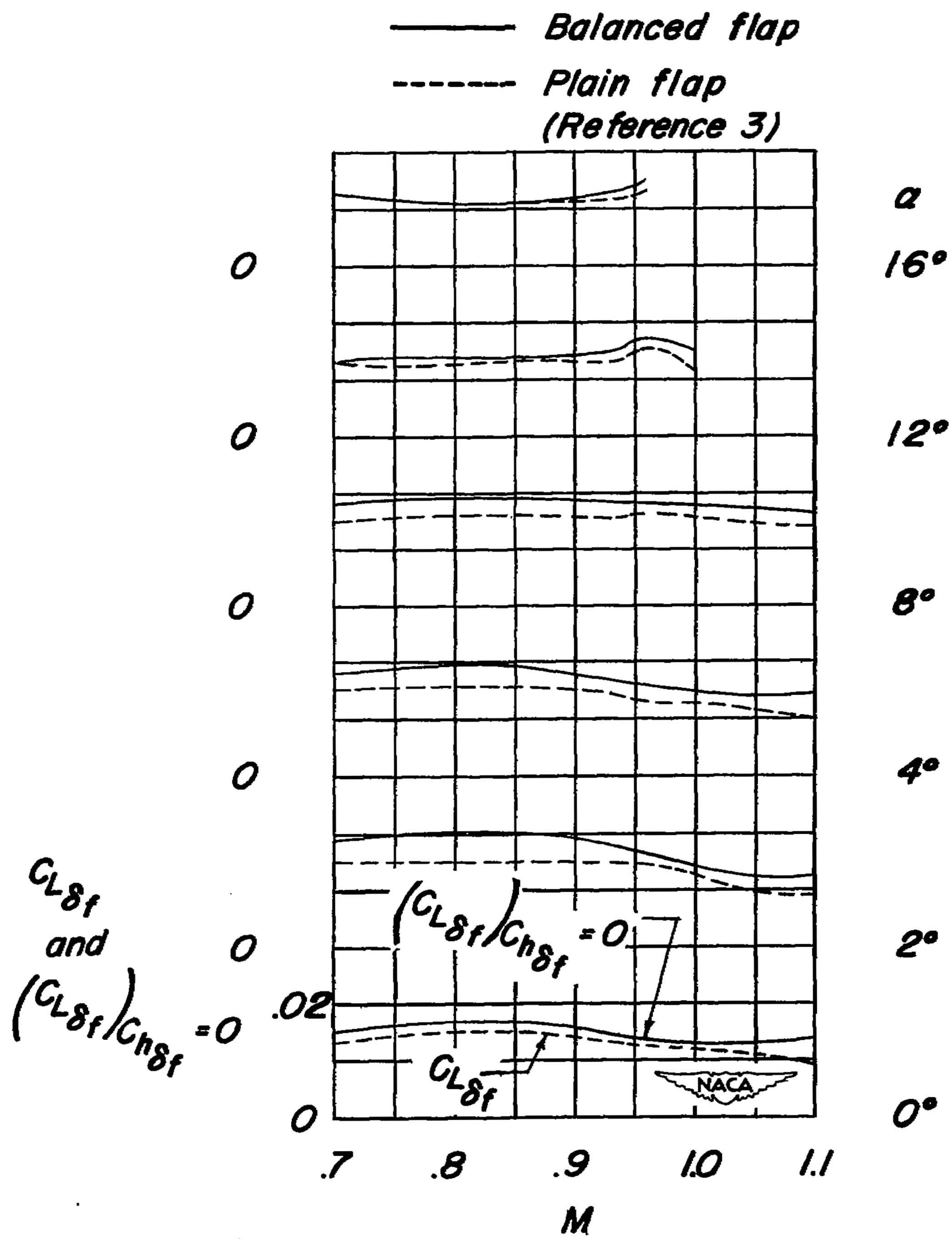


Figure 12.- Comparison of the lift parameters of the plain flap and the balanced flap $\left(C_{h_{\delta_f}} = 0\right)$ for various Mach numbers and angles of attack.

$C_{L_{\delta_f}}$ based on the deflection of the flap in the free-stream direction.

NACA-Langley - 11-20-52 - 350

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